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WATERSHED MANAGEMENT IN THE BLACK HILLS:

The Status of Our Knowledge

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Abstract

Climate, geology, soils, vegetation, and water yields are briefly described, followed by a review and discussion of watershed management research and problems unique to the Black Hills. Research needs with respect to water quality, data collection, and model development are highlighted.
Keywords: Multiple use, coniferous forest, forest management, vegetation effects, land use planning.

ABOUT THE COVER:

Forest, Water, City, The Plains. The forest land yields the water that is stored in the reservoirs and is in turn fed into the water supply system of the city. This forest/water system is in stark contrast with the surrounding semiarid Plains, and plays a dominant role in the strong esthetic appearance of the area.

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[1]Central headquarters is maintained at Fort Collins, in cooperation with Colorado State University; research reported here was conducted at the Station's Research Work Unit at Rapid City, in cooperation with the South Dakota School of Mines and Technology.

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The Black Hills Region

Location and Extent

The Black Hills are a forested island in the vast expanse of the Northern High Plains, covering about 5,150 square miles in southwest South Dakota and northeast Wyoming. Because of the pine forest (fig. 1), more water, and a more temperate climate, the Hills are especially attractive to the tourist and traveler as well as the resident population.

Figure 1.—A typical Black Hills scene showing the dominant ponderosa pine, scattered deciduous species, and streambottom meadow. The granite heart of the Hills is visible in the far background.

Climate

General climate in the Black Hills area is of the Continental type (Johnson 1949), which is typically cold in winter and relatively hot in summer. The Hills receive more precipitation and average temperatures are lower than in the surrounding Plains, but both precipitation and temperature extremes are less. Orographic effect is pronounced—the area has been cited as one of the best examples in the interior United States (Foster 1948). Winter effect is especially pronounced.

Temperature.—Temperatures are higher at comparable elevations in the southern than in the northern Hills. For example, average annual air temperature at Hot Springs in the southern Hills is 48.8°F, 2° higher than at Spearfish in the northern Hills. The difference is greatest in the growing season, which extends from about mid-May to mid-October at these lower elevations.

Precipitation.—Greatest average annual precipitation, nearly 30 inches, occurs in the northern high Hills and in the Bear Lodge Mountains. Amounts decrease rapidly toward the Plains (14 to 16 inches) and from north to south along the uplift. Average annual precipitation is about 2 inches more at comparable elevations in the northern than in the southern Hills. These and other precipitation factors have been reviewed and summarized by Orr (1959).

Seasonal distribution of precipitation is similar to that of the surrounding Plains; greatest amounts fall in the form of rain in the spring and early summer months. May and June are the maximum months, May in the southern Hills and June in the northern Hills. Minimum amounts fall in the winter. Though snow is a relatively minor component of annual precipitation, heavy wet snows are not uncommon in March, April, and even May. These are produced from weather systems moving southwest to northeast across Nevada, Utah, and Colorado. Circulation about lows moving in this direction draws warm moist air from the south.

Year-to-year variation is great. For example, annual precipitation at Rapid City has ranged from a maximum 28.89 inches in 1962 to minimum of 7.51 inches in 1936—a ratio of

nearly 4 to 1. In the drier years there is little excess water (over evapotranspiration) for streamflow. In the average to maximum years, water available for streamflow increases with precipitation. The Black Hills are subject to infrequent extreme flood events. Flash floods after the most recent storm, in June 1972, caused unprecedented damage and loss of life (Orr 1973).

Growing season.—Average growing season ranges from a maximum of about 154 days at Rapid City to a minimum of just under 100 days in the higher northern Hills. The general area of shortest growing season also receives maximum precipitation, and is in the zone of highest water-yield potential.

Winds.—Prevailing winds are westerly. During CY 1970 (the best one year of several years' record) 67 percent of recorded wind movement was from 225° to 315° at the Black Hills Experimental Forest. Averages were 115 miles per day and 4.8 miles per hour at 10 meters above ground level in the center of a 5-acre forest opening. The maximum month was April, with an average velocity of 6.6 miles per hour. During this 1 month, 76 percent of total recorded miles were in the west quadrant (225° to 315°).

Sunshine.—Total incident solar radiation (wavelength 0.36 to 2 micrometers) on a horizontal surface at the Black Hills Experimental Forest averaged 398 langleys per day over a period of 3 years (1968-70). Day averages ranged from a maximum of 593 langleys in July to a minimum of 184 in December.

Physiography and Geology

Primary structure.—The Black Hills and Bear Lodge Mountains are erosion remnants of ancient domal structures formed by granites pushing up beneath overlying sedimentary formations. Processes and resultant general geology are best described by Darton and Paige (1925). More than one cycle of raising and lowering occurred. The upthrusting granite and later igneous intrusions resulted in metamorphism of overlying sedimentaries. More sediments were later deposited. Sedimentary formations have since eroded away, exposing the granites (fig. 2) and metasediments which are collectively called the central crystalline area. The truncated edges of the eroded sedimentary formations now are exposed as a series of ridges encircling the central crystalline area (figs. 3 and 4).

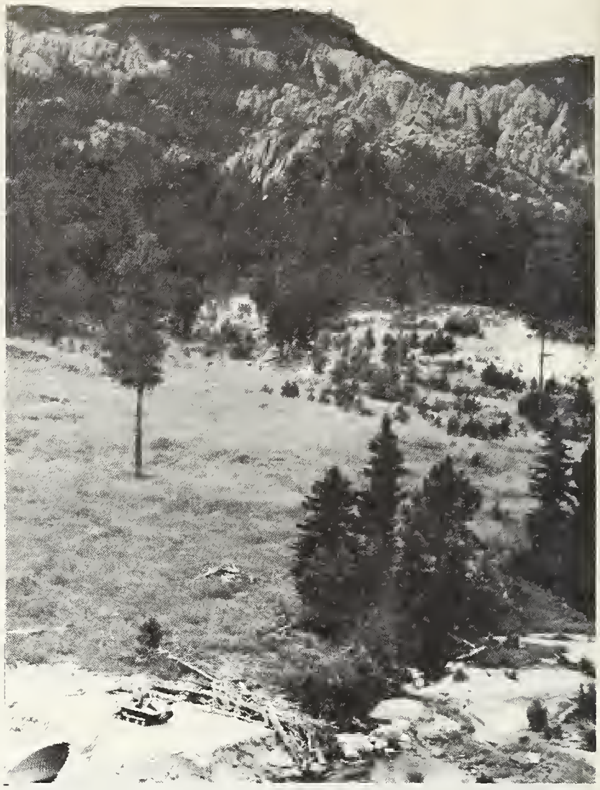

Figure 2.—Typical terrain in the granite "core" of the Black Hills. High point in center background is Harney Peak, the highest in the Black Hills (7,242 feet). Soil lacks cohesion and is highly erosive.

The sedimentaries include 12 or more separate formations. Rock types vary greatly, in some cases within individual formations, and range from limestones and sandstones to shales and conglomerates. The central crystalline area, which includes the Precambrian granites and metamorphics, occupies about 20 percent of the Black Hills area and is relatively impervious to water. This is of particular management significance because the most dependable and constantly flowing streams in the Hills originate in or flow across the crystalline area. But the flow of these streams diminishes or disappears during at least a part of each year where they cut the encircling sedimentary formations. This has been a major water problem from the start of settlement (Brown 1944). Pahasapa limestone (fig. 5), in particular, is cavernous and evidently takes in, stores, and transmits large volumes of water.

There are a number of Tertiary intrusive areas across the northern Hills. These areas are a relatively small proportion of the total Black Hills area, but research and observation have

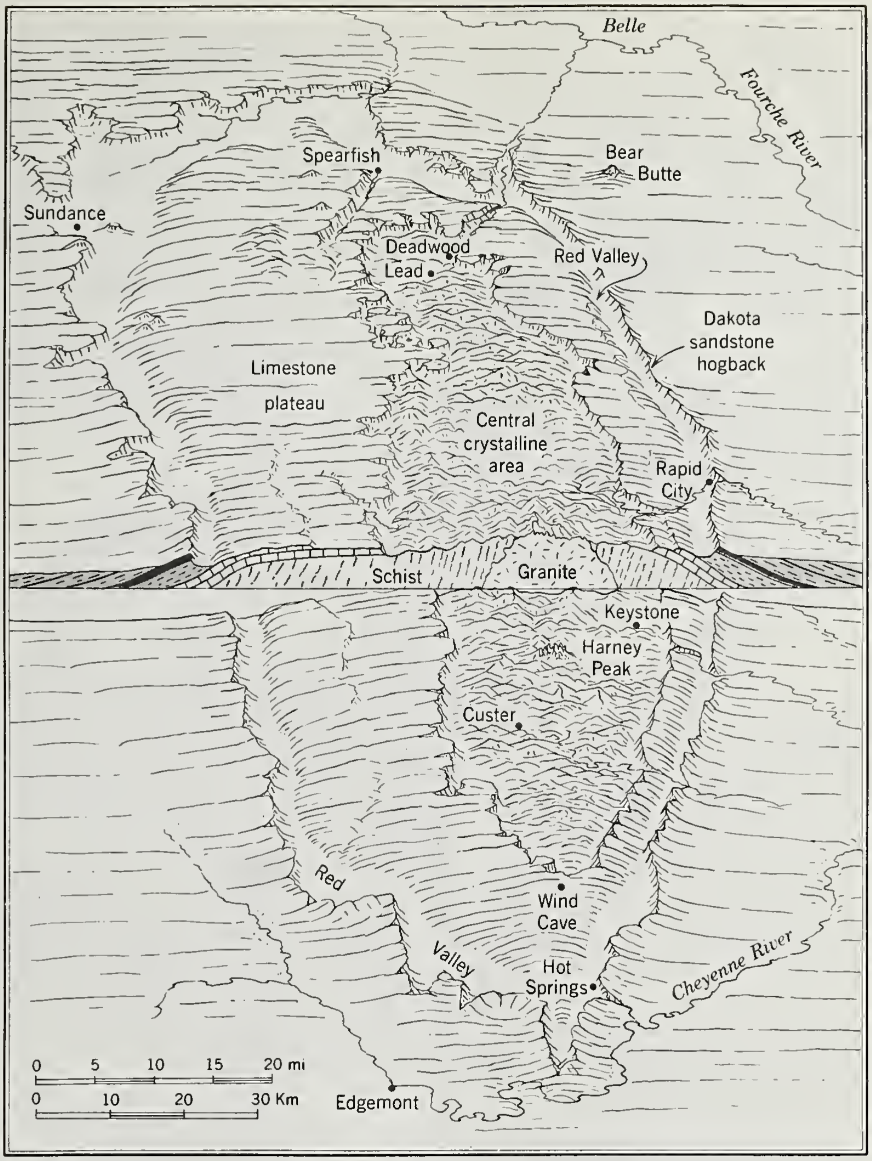

Figure 3.—Main topographic regions of the Black Hills of South Dakota and Wyoming (from Strahler's Physical Geography, 3d ed., copyrighted 1969. Reprinted by permission of John Wiley & Sons, Inc., N.Y.)

indicated that, from a surface water standpoint, they are of much greater importance than indicated by their percentage of total area (see fig. 2). These intrusive bodies and adjacent areas are relatively impermeable, and thus are dependable sources of surface water yield. These areas very likely have the greatest management potential for water-yield increase of any in the entire region.

Relief.—Elevation ranges from about 3,200 feet (m.s.l.) at Rapid City to a maximum of 7,242 feet at Harney Peak in the granite area. Elevation is nearly as high along a segment of sedimentary formations in the west central Hills referred to as the Limestone Plateau (see fig. 2). Through the approximate 4,000-foot range in elevation in the Hills, there are wide variations in climate, geology, topography, soils, and vegetation.

Drainage pattern.—The present drainage, definitely related to physiographic and geologic history, is of a radial-dendritic pattern. Thus,

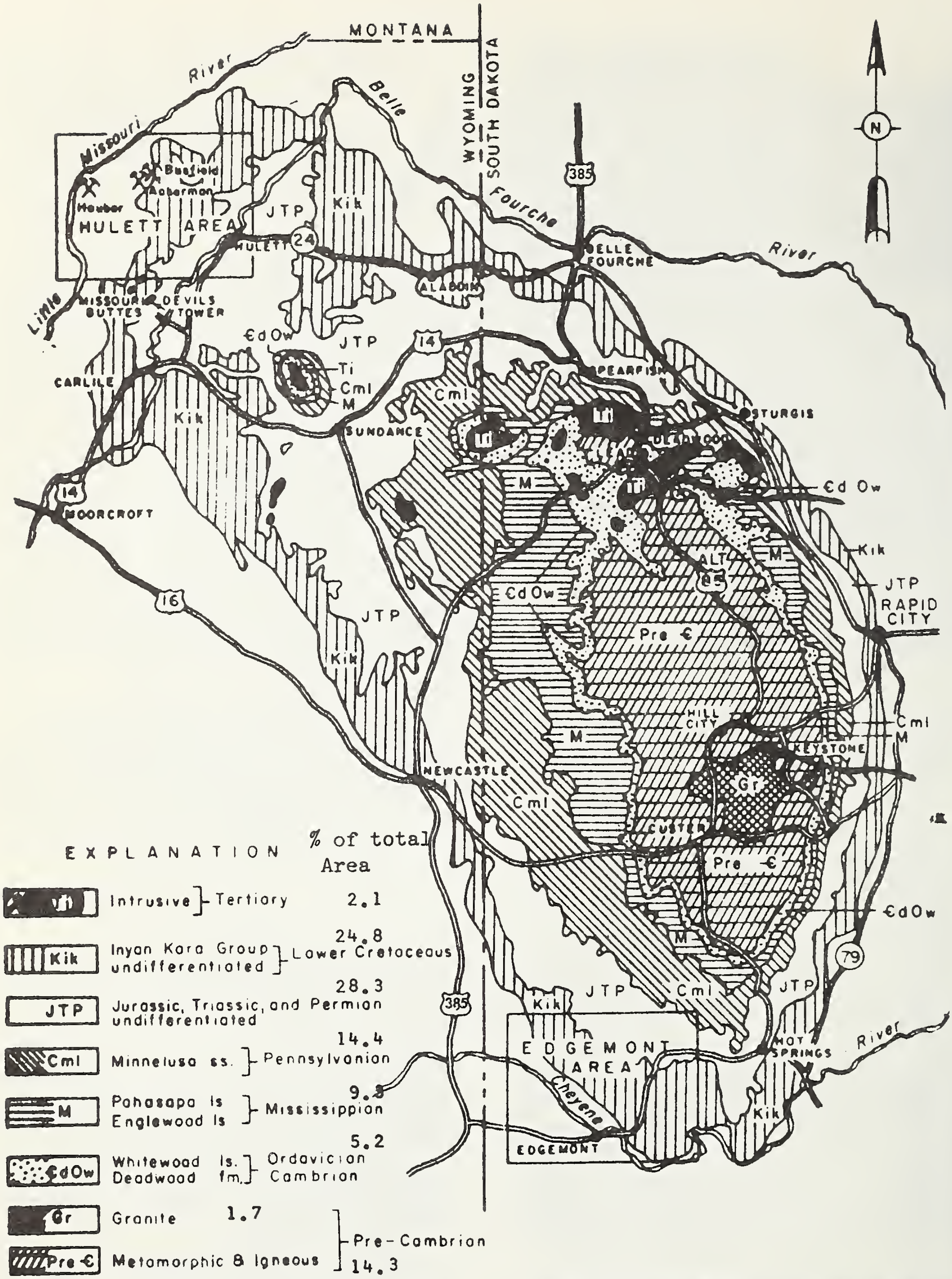

Figure 4.—Generalized geologic map of the Black Hills uplift area. (Reproduced by permission of Homestake Mining Company, Lead, S. D.)

Figure 5.—Massive limestone (Pahasapa formation), a primary water loss zone in the Black Hills.

many of the streams cut through the peripheral sedimentaries at nearly right angles (fig. 6).

One feature of particular significance to watershed management is the diminution or complete disappearance of flow where streams cross sedimentary formations (Brown 1944). These channel segments are recharge zones to aquifers which are important ground-water sources and still have a large untapped potential. At the same time, the diminution or disappearance of flow means that surface water yields can be significantly increased only in areas upstream from the loss zones—except in the case of floods or other high flows that exceed the intake capacities of channels.

Surface water yields (upstream from loss zones) can be increased in the Black Hills only by management of relatively small amounts of water at many locations (a large number of relatively small streams).

Soils

Ridge and slope soils in areas of granite and metamorphic parent materials are relatively shallow, coarse textured, and porous. The more easily transported fines have been deposited on lower slopes and in the valley bottoms. Hence the valley soils are generally finer textured, deeper, and more fertile. Topographic stratifications of soils are similar in areas of sedimentary formations. However, the soils are, in general, finer textured. Clays and clay loams are not uncommon, particularly in limestone areas.

In broad terms, the soils of the Black Hills classify as "gray wooded" (Westin et al. 1959, Radeke and Westin 1963). This is a broad classification indicative of the relatively humid forest environment in which the soils have developed. In this subhumid to humid climate and under conditions of rapid drainage, the surface layers leach rapidly, leaving an A_2 horizon of distinctive ash-gray color and as much as 10 to 12 inches thick. Deposition in the B horizon has resulted in fairly well defined blocky structure, depending on parent material, and a definite brown color.

Azonal soils also are present, including regosols, lithosols, and alluvial soils. Zonal soils with characteristics of both true prairie and gray wooded series occur in the open grassland and "prairie" areas of the interior Hills (White et al. 1969). Zonation varies from weak to strong. The more pronounced similarity to gray wooded soils of forest origin suggests that soils in these areas developed under forest.

Vegetation

In the cooler, more humid climate of the Black Hills uplift, forest cover is dominant—a sharp contrast with the grass cover of the surrounding plains. The forest, in turn, is dominated by ponderosa pine[2] except on more moist sites in stream bottoms and on north-facing slopes where white spruce grows—often in nearly pure stands. In contrast to much of its natural range, ponderosa pine reproduces easily in the Black Hills. "Dog hair" stands are common.

Interspersed with these two conifer species are small amounts of quaking aspen and paper birch on the more moist sites. Willow, red-osier dogwood, and water birch are found along many of the streams.

Comprehensive reports on the state of our knowledge in timber management in the Black Hills are given by Alexander (1974) and Boldt and Van Deusen (1974).

Although "forest" characterizes the Black Hills in general, there are numerous open meadows, parks, and "prairies" (fig. 7) ranging up to hundreds of acres in size. Here are found representatives of the true prairie, the plains, and Rocky Mountain floras.

Many narrow stream bottoms (fig. 8) support herbaceous cover. Kentucky bluegrass is a dominant species. These stream bottoms are some of the most productive and most highly favored livestock range in the Hills area. Con-

[2]Common and botanical names of species mentioned are listed inside the back cover.

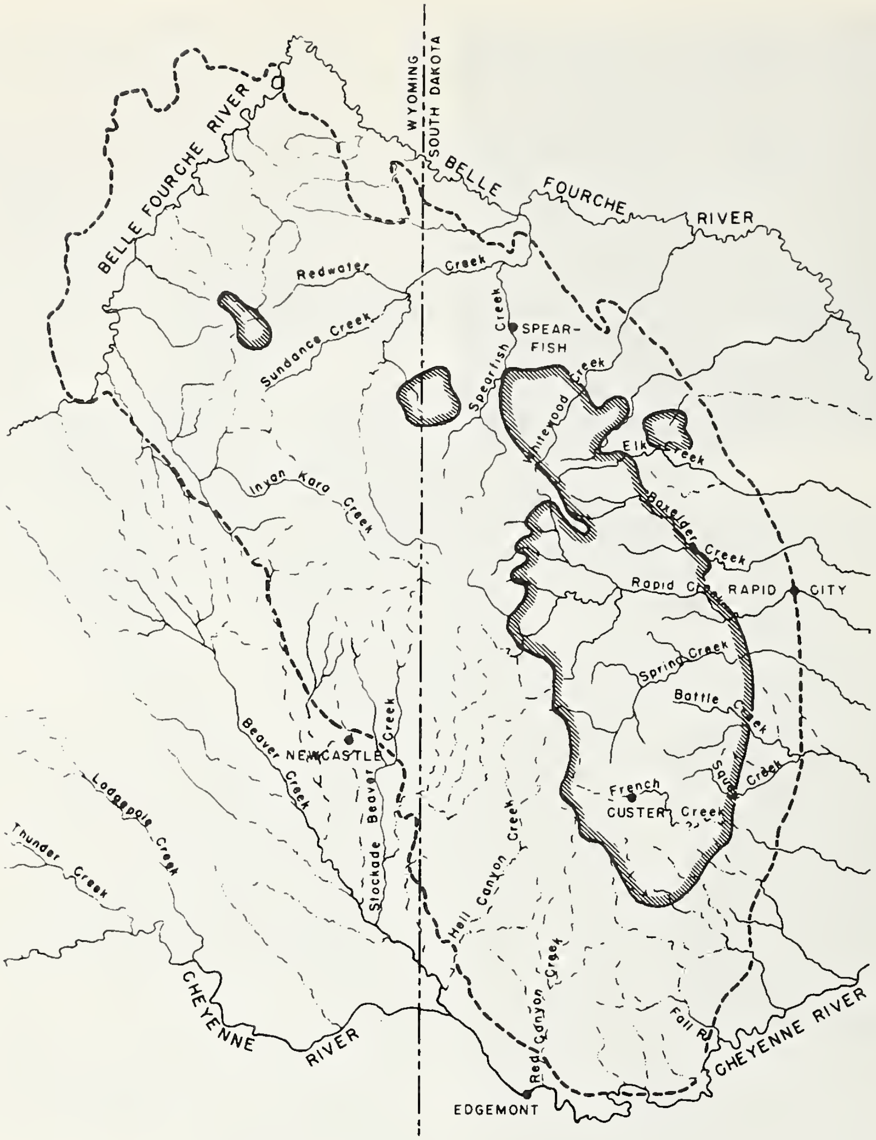

Figure 6.—Drainage map of the Black Hills and Bear Lodge Mountains. The heavy dashed line is along the sedimentary formation of the outer encircling ridge. The hatched lines encircle areas of metamorphic and igneous rock formations. Sedimentary formations are found in the remainder of the area (Orr 1959).

sequently many areas have been subjected to heavy use. Ranch and farm properties, many of them originally homesteads, are dispersed within the boundaries of the National Forest in and adjacent to stream bottoms.

These descriptions are of vegetation as we see it today. Actually the region has a unique intermixture of northern, southern, western, and eastern elements in the flora (Hayward 1928). For example, the dominant ponderosa pine is a western species. Typically eastern species include bur oak, American elm, boxelder, and hophornbeam (ironwood). Black Hills spruce and paper birch are typical northern species. Southern species are predominantly shrubs. True prairie species are found in the foothills and in some "prairie" areas within the Hills. Similar relationships have been described by McIntosh (1949). An up-to-date listing of the vascular plants of the region with their presently accepted scientific names was published by Thilenius in 1971.

Figure 7.—Gillette Prairie, one of the number of naturally treeless areas within the confines of the Black Hills. Representatives of true prairie flora are found in such areas.

Figure 8.—A typical "bluegrass streambottom." These are highly favored cattle and sheep ranges. White spruce grows low on the north facing slope (left). Remnants of quaking aspen, white birch, and willows are also present. Beaver were once present but they have been trapped or have starved themselves out. Almost all dams are broken and eroded. Roads are present in virtually all such stream bottoms in the Black Hills.

The Water Situation

The trend in the Black Hills is toward more intensive management of smaller areas. Information and means of satisfactorily modeling the hydrology of small areas are available for subalpine and Montane forests (Leaf 1975, Gary 1975). The technology developed for these areas and information presently available in the Black Hills will provide a sound basis for a higher level of watershed management in the future. There is still a need, however, to adapt the modeling approaches presently being developed for the Rocky Mountain region as tools in decisionmaking for the Black Hills. These models are essential to our understanding of natural water relations, how these relations have been and are influenced by man, projections of need and demand, and capacity of the area to meet demands without serious deterioration of the environment. Inventory of water quantity and quality is necessary, together with other elements of the environment that are known to significantly influence the production and utilization of water.

Water Yield

Flow is measured by the U.S. Geological Survey on most of the main streams, but usually downstream from zones of water loss into the sedimentary formations. Yields, including subsurface, are therefore greater than indicated by published figures. Surface yields from three gaged streams on the Sturgis Experimental Watersheds (fig. 9 and 10) averaged slightly in excess of 7 inches per year, almost exactly 25 percent of precipitation, from 1964 through 1969. Losses, closely approximating total evapotranspiration, were 21 inches per year (Orr and VanderHeide 1973). Except for the Sturgis watersheds, there are virtually no data for sizes of areas now considered in unit area management plans.

Watershed management is complicated by the large number and diversity of small drainage basins. Management objectives are thus more variable and the planning processes are more complex than in areas where only one or two streams are involved.

No areas have been or now are managed primarily for water-yield increase in the Black Hills. One reason is that much developmental work can be done to improve utilization of presently available water. A second is concern about our ability to increase water yield, and at the same time maintain site stability. Although these reasons are judgmental, they are nevertheless based on general knowledge of the Hills and well-established hydrologic principles.

Figure 9.—Area of the three Sturgis Experimental Watersheds, on the Vanocker Laccolith in the northeastern Black Hills. These watersheds are instrumented for basic hydrologic studies and evaluation of the effects of timber stand manipulation on quantity and quality of water yield.

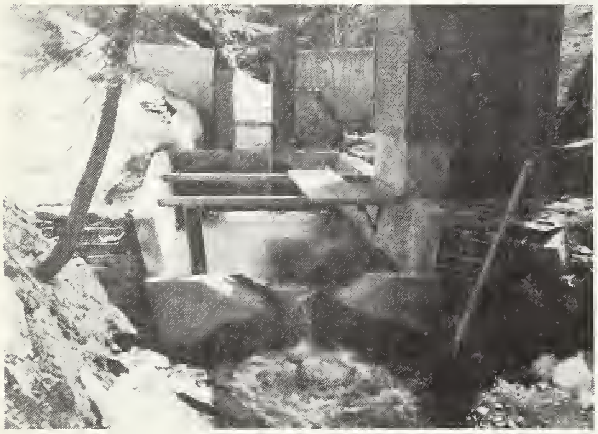

Figure 10.—Spring runoff from one of the Sturgis Watersheds. Station is a tandem San Dimas flume for measurement of high flows and a 120° V-notch weir for measurement of low flows.

Water Quality

In land and forest management in the Black Hills, concern for water is focused primarily on quality. Some quality problems stem from inherent geochemistry of source areas and others from land and water use.

Chemical quality.—The surface waters of the Black Hills are of better chemical quality for domestic use than any other waters in the State (South Dakota Department of Health 1966). Content of dissolved solids varies with season, (lowest during high flow periods) but it is consistently less than for wells in general, though increasing numbers of wells are being drilled to obtain domestic water. Well waters vary from moderate to very hard. Total dissolved solids increase rapidly with increasing distance from the Hills, and generally with increasing well depth.

From a limnological standpoint, surface waters from areas of limestones and associated formations in the Hills contain largest amounts of essential nutrients and are the most productive. Waters from metasediment areas are less productive because the rock is less soluble. Water originating in granite areas is still less productive.

The iron problem.—One of the best known problems of water chemistry in the Black Hills involves "bog iron" in some areas of metasediments, particularly in upper Rapid Creek tributaries. The general problem of iron mining and aquatic resources in the Black Hills has been reviewed in detail by Lyons.[3]

Limited areas of bog iron have been mined, leaving channels in practically sterile condition despite diligent rehabilitation efforts. Although some areas have been regraded, top soil replaced, and lime applied, acidity along the channels remains too high for most plants to establish and grow. Channels are a distinctive rust red color. This color, plus the higher-than-average acidity and precipitation of phosphate in combination with iron, are detectable considerable distances downstream. This problem has also been discussed in considerable detail by Stewart and Thilenius (1964). Not many areas have been mined, but some rather extensive stream bottom areas remain where bog iron concentrations are known.

Roads and sedimentation.—"Quality" is rated the number one water problem in the Black Hills, sedimentation is most often cited as the number one quality problem, and roads are most often cited as the number one source of sediment. The Hills are interlaced with an extensive network of both old and new roads, a large proportion of which are in or near stream bottoms (see figs. 5 and 8). New roads are built with important elements of environment taken into account, but such was not the case with

[3]John R. Lyons. Iron mining and aquatic resources in the Black Hills. 14 p. (Unpublished report presented at the meeting of the Board of Directors of the Black Hills Conservancy Subdistrict, March 29, 1966.)

most old roads. A large part of the old road network served logging, mining, or other utilitarian land uses. The locations and grades were dictated by intended use, and limitations of equipment that would be traveling the roads. Seldom were special precautions taken to keep a road stable during use or to stabilize it later.

Although many old roads, more by chance than by design, were located and constructed in such a way that they stabilized and remained stable, there remain segments that need attention—a situation that is particularly evident after a flood (Orr 1973). Trouble areas most often encountered are steep pitches in grade and channel bottoms. Two types of areas are especially susceptible—soils that are highly permeable but with low cohesion and hence erodible (as in granite areas, see fig. 2), and soils that are medium to fine textured, easily compacted, and hence subject to larger volumes and more rapid runoff for given rainfall.

The significance of primitive roads has increased greatly with the advent of four-wheel-drive vehicles, motor bikes, snowmobiles, and all-terrain vehicles (ATV's). Many old roads now receive more use (or would if use were allowed) within a few years than they did in several prior decades. Thus the undesirable effects of poor locations of old roads are in some cases more evident now than they probably were in the early years following original construction.

Many old roads have been closed, and methods are available to stabilize "sore" spots once they are recognized and included in management planning.

Research Perspective of Knowledge Base

Hydrology

Enough is known about the hydrology of the Black Hills to define general characteristics of climate and streamflow. Pertinent relationships were reviewed by Orr (1959). A complication, however, is that although a considerable number of measuring stations (mostly standard gages) are scattered about the Hills, there are extensive areas in which few or no records are available. These have been interpolated into isohyetal maps, but uncertainty levels are high.

The scarcity of time distribution records of precipitation (from automatic recorders) was dramatically illustrated during the June 9, 1972, storm which produced record floods in Rapid Creek and other watersheds draining to the east out of the Black Hills. Certain areas are known to have produced unprecedented rates and amounts of runoff (Orr 1973), but without intensity records it is impossible to realistically estimate flow separation components or how much flood flow was due to overwhelming volumes of falling water. Recognition of waterflow and quality problems in relation to land use was practically impossible in this situation.

As we develop more explicit hydrologic models, pertinent climatic and atmospheric factors will need to be more precisely and more extensively measured. Experience has shown that the primary variables should include precipitation, temperature, and radiation (Leaf and Brink 1973). These variables will have to be measured at locations and in terms compatible with modeling concepts and goals.

Vegetation

National Forests have been under relatively intensive management for more than a half century. According to Alexander (1974), "Regeneration silviculture in the Black Hills has been learned by experience during nearly a century of harvesting that has included all silvicultural systems, and led to the replacement of the original old growth by well-stocked, manageable second-growth stands." There is, therefore, a large volume of forest inventory data and knowledge already in existence (Boldt and Van Deusen 1974). Data are being added continuously, but mainly through routine timber sales and inventories.

Vegetation complexes other than trees are highly variable in both composition and distribution. Such variability is due to type of land use, climate, forest cover, geology, exposure, soils, and probably other factors. Hence, species occurrence is predictable only within very broad geographical limits. Variations in distribution very likely affect moisture relations and water yields, but such relationships are known only in very general terms. Efforts to gain more exact information will depend on the need for more exact prediction of watershed behavior and response to changes in management.

Fortunately, from the standpoint of site stability, several introduced herbaceous species are adaptable over extensive areas in the Hills. One obvious reason is the concentration of precipitation in the early part of the growing season when moisture for plant establishment is most critical. On most sites, given a reasonable chance, vegetation reestablishes quite easily. This is one of the main reasons why there are no large sediment source areas in the Hills. Unstable sites are usually so obvious—for example, lack of soil, hyperacidity, or steepness

of slope—that the manager would recognize the problem potential.

If there is a seed source close enough, forest cover will in time reestablish itself in most denuded forest areas. Areas which will not come back to forest cover are usually recognizable and plans can be made to seed or plant.

Soils

Lack of soils information is a serious hindrance to watershed management in the Black Hills. In general, soils characteristics relate to the parent materials but are less variable. In other words, broad soil classes occur across a broad range of geologic types that are known to have significantly different water yield characteristics and potentials. For example, gray wooded soils occur in areas where parent materials include a variety of sedimentary formations, metasediments, and also igneous rocks. Thus the classification is broad and needs improvement for modeling and more effective unit area management.

Information relating soil physical characteristics to land use is limited. Orr (1960) demonstrated that soil in grazed bluegrass meadow areas is more compact and has less pore volume than soils in exclosures protected from livestock trampling for 5 to 20 years. In a followup study it was found that improvement is relatively slow in terms of reduced bulk density and increased pore volume, especially in medium-textured soils, which are more susceptible to compaction than either coarser or finer textured soil. Thus 1 year of rest in a rotation grazing system is not likely to significantly improve soil conditions. Several years of protection may be necessary. The hydrologic impacts of grazing mountain ranges have been discussed by Gary (1975).

Geology and Physiography

Water-yield significance of these factors is known in broad terms. General relationships have been described by Darton and Paige (1925) and by many others. Published material usually lacks the detail needed for systematic refinement of geologic and physiographic elements in management analysis and design, however.

Detailed information is being obtained from the Sturgis Experimental Watersheds. Hydrologic implications of geomorphology have been carefully analyzed by a unique approach involving dimensional analysis (Yamamoto and Orr 1972). In this approach, we have attempted to refine the accounting of geological and morphological factors, which in the past have been dealt with almost exclusively on a broad regional basis.

Geophysical analysis of mantle depths, physical characteristics, and distribution are progressing. In each case, hydrologic implications are analyzed. This meshing of geologic and hydrologic (or hydraulic) elements will be necessary before geologic elements can be accounted for on smaller than a regional basis. As stated by Reene (1967), " . . . many researchers have found that the principal difficulties in applying research results from one watershed to another adjacent and seemingly identical watershed **lie below the surface.** Top watershed scientists have noted that soil and geologic properties, in particular, are poorly defined as they relate to moisture storage and transmission."

Timber/Water Relationships

Irregular patchcutting will produce maximum increases in water yields (Leaf 1975). Studies in the subalpine zone of central Colorado have indicated that patchcutting changes the usual snow distribution pattern by increasing snow accumulation in cleared areas where it melts more efficiently. Because recharge requirements in openings are less, more water is available for streamflow. The same principles apply to the Front Range pine zone in Colorado (Gary 1975) and to the Black Hills. Irregular patchcutting of some portion of first-order basins and interbasin areas would generate water-yield increases in a topographic position (bedrock channels in many places) where conveyance and other losses would be minimal.

Moisture disposition in dense second-growth pine was measured in a series of study plots—clearcut versus thinned (80 ft^2/acre basal area) versus unthinned (190 ft^2/acre basal area). The dense unthinned stand intercepted about 25 percent of precipitation, while the thinned intercepted only about half as much. Net interception (taking stemflow into account) can be estimated for different measured canopy densities (Orr 1972).

This same study also provided information about soil-moisture disposition. The thinning reduced soil-moisture demand, resulting in less soil-moisture deficit (Orr 1968) and greater potential for seepage to ground water. The study was carried out in a period of increasingly severe drought, and practically no seepage to ground water was observed except in the clearcut, which for a time was kept bare of vegeta-

tion. There the moisture surplus continued despite drought—until a luxuriant weed and grass stand was allowed to become established and quickly depleted the available soil moisture to 6 feet or deeper. Studies in other areas have shown that thinnings result in lesser soil moisture savings and small or negligible increases in streamflow, even during good years (Leaf 1975, Gary 1975, Rich 1965).

Further Research Needs

Several water-related questions remain in design and application of watershed management. One has to do with the range of timber stand conditions—taking all relevant site factors into account—that will produce significant increases in water yield. Exploratory soil moisture measurements have been made to as deep as 24 feet in large sapling stands, 20 level stocking.[4] At this stocking level there were definite soil-moisture gradients across the space between trees, indicating less than full site occupancy. At high stocking levels, 80 or higher, it is questionable whether any increase in yield could be achieved. Therefore, there is a broad range of vegetal patterns within which water yields can be significantly increased.

Geology and geomorphology are significant, inseparable parts of all systems related to water-yield improvement. These space variables need more study in a variety of situations and locations in the Black Hills to provide better guidelines for land use planning.

Questions having to do with the range of applicable land use options and treatments which will improve water yields without deterioration of environment are many. For example, how much timber can be removed without triggering accelerated soil erosion? How much and in what patterns should timber be harvested to promote establishment of desirable vegetation? What are safe limits of other land uses? The manager should know his options with respect to the best use of the land and water resources. Adaptations of available hydrologic and land use models to the Black Hills would help him determine these options.

Summary and Conclusions

The pine-forested Black Hills are an important water-yielding area, both for surface flow and ground-water recharge. Because the area is an island of forest and flowing streams in the broad expanse of the northern High Plains, it is especially attractive to the traveling public. Therefore esthetics are especially important.

Quality is an ever present water problem in the Hills; sedimentation is the primary quality problem, and roads are most often cited as the main source of sedimentation. Nowhere are there large problem areas, however. Instead, problems are small and relatively scattered. Corrective measures are especially complex and expensive under these conditions.

The extensive network of old roads in the Hills is especially troublesome. Many are located in stream bottoms or on steep grades. With the advent of the four-wheel-drive vehicles, motor bikes, snowmobiles, and ATV's, intensity of use may actually be greater in places now (or would be if allowed) than it was when roads were in intended use, mostly utilitarian, many years ago. Stability problems have grown accordingly.

A chemical quality problem exists in and downstream from stream bottom areas mined for bog iron. Fortunately, these areas are few in number. Despite intensive restoration efforts, some areas remain practically barren after many years. Further mining of bog iron should be discouraged unless methods are developed that will insure site stabilization within a short time.

Quantity of water yield cannot be ignored, though no part of the Hills is now or ever has been managed specifically to increase water yield. Some reasons for this are the current overriding importance of quality and uncertainty about land use. Because increase in demand for water is as inevitable as increase in population, the possibility of need to increase yield must be considered in land use planning.

One key to sound management planning is careful inventory of pertinent resource factors and relationships, which vary greatly within the relatively small area of the Black Hills. While this variability is a complicating factor in management, it is an ideal situation for research because a wide variety of conditions can be sampled and studied within a relatively small geographic region.

Watershed management in the Black Hills can be improved most easily by adapting technology developed here and elsewhere in the Rocky Mountain region. Irregular patchcutting, which produces maximum water-yield increases without causing adverse ecologic effects can be expected to produce similar results in the Black Hills.

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Climate, geology, soils, vegetation, and water yields are briefly described, followed by a review and discussion of watershed management research and problems unique to the Black Hills. Research needs with respect to water quality, data collection, and model development are highlighted.

Keywords: Multiple use, coniferous forest, forest management, vegetation effects, land use planning.

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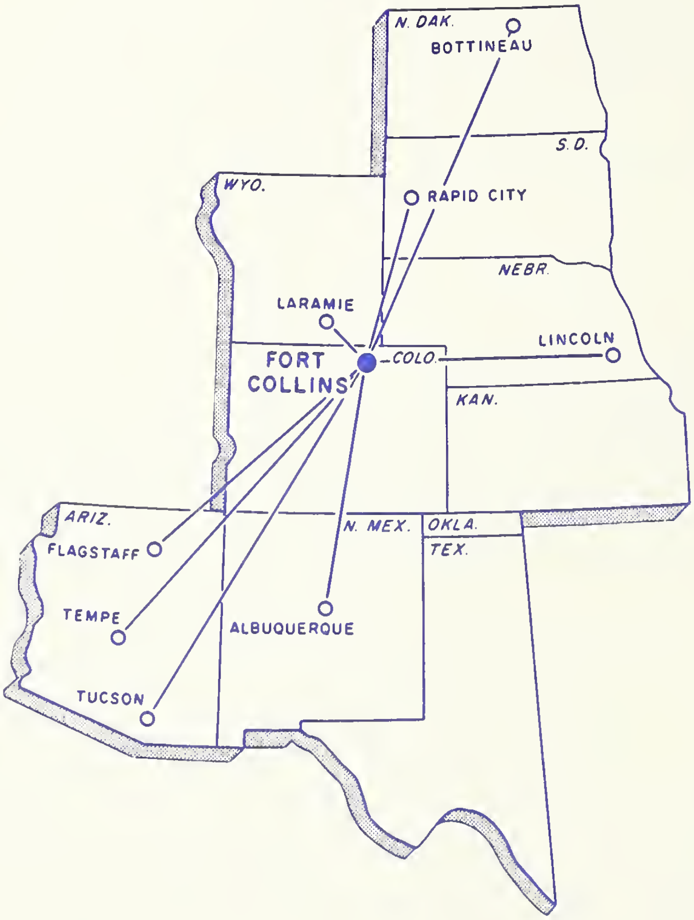
Common and Botanical Names of Species Mentioned

Aspen, quaking	*Populus tremuloides*
Birch, paper	*Betula papyrifera*
Birch, water	*Betula occidentalis*
Bluegrass, Kentucky	*Poa pratensis*
Boxelder	*Acer negundo*
Dogwood, red-osier	*Cornus stolonifera*
Elm, American	*Ulmus americana*
Hophornbeam (ironwood)	*Ostrya virginiana*
Oak, bur	*Quercus macrocarpa*
Pine, ponderosa	*Pinus ponderosa*
Spruce, Black Hills (white)	*Picea glauca* var. *densata*
Willows	*Salix* spp.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